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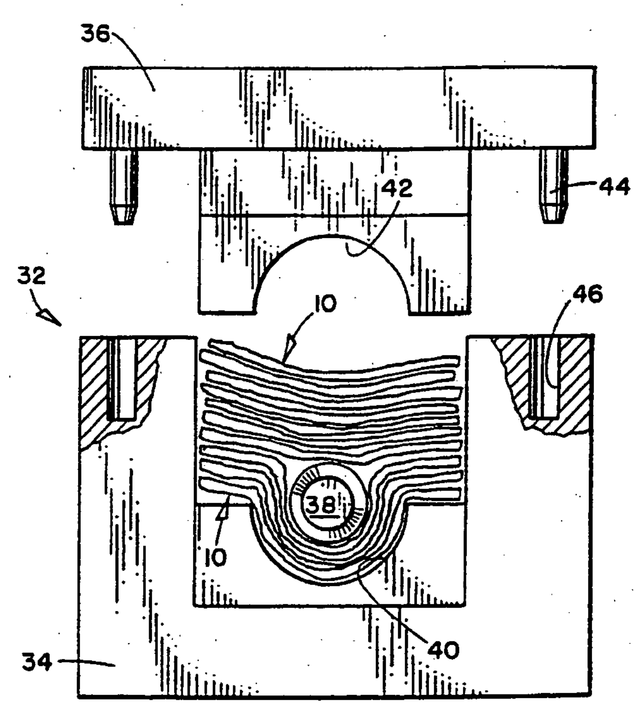

(57) Abstract

An expendable, molded device is disclosed. The device is a composite of resin and fiber molded into a preselected shape. The composite includes an effective amount of fiber having an aspect ratio sufficient to produce a device with high compressive and tensile strength but having limited abrasion resistance. Use: Tools for earth drilling.

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EXPENDABLE COMPOSITE FIBER DEVICE

Background of the Invention

Field of the Invention

The present invention relates to metal replacement components or parts and, more particularly, to composite structures for metal replacement. Specifically, the present invention relates to devices having high tensile and compressive strengths yet are readily expendable by abrasive destruction.

Description of the Prior Art

Many components and tools in a wide variety of industries and product applications are made from steel, iron, aluminum and other metals because of their useful physical properties. A few of the major physical properties of such metal components and tools are their hardness, their high tensile strength as well as their high compressive strength. There is currently a desire in a variety of industries, as well as in a variety of product applications, to replace at least some of these metal components or tools with components or tools made from a nonmetallic material. A major concern for such alternative materials has generally been weight, although the material selected must perform all the functions of the original metal components or tools. One such industry is the aircraft industry wherein metal parts, including wing skin, have been replaced with composite material in lieu of metals. Likewise, the automobile industry has replaced numerous trim parts and body parts with composite materials in lieu of the original metal materials, again reducing weight while maintaining strength and environmental resistance.

One industry of particular concern is the well drilling industry wherein many parts and tools are metal and used for their physical property of high tensile and compressive

strength. In this particular industry, many of these parts and tools need to be placed in a well, used, and then "drilled through" or abraded away at a later time rather than being physically removed from the well in tact. Typically, drill bits designed specifically to drill through rock are not of an optimum or especially desirable design for drilling through and destroying such metal components or tools. This situation necessitates either accepting a much slower rate of travel of the rock drill bit while it is in fact drilling through the metal component and abrading it, or pulling what is possibly an extremely long string of pipe from the well bore in order to attach a different style of drill bit onto the end of the string and then sending it back down into the well to drill through the metal part. The selected method employed is generally determined by the then current depth of the well as opposed to the rate at which the then current "rock bit" is able to drill through the metal parts. In either event, each of these two methods of drilling through and expending the metal part or tool substantially decreases the average drilling rate of travel, which is a highly undesirable situation in the drilling industry.

In the above instance, it is a desire in the drilling industry to replace at least some of these metal tools or components with tools or components made from a nonmetal material that can be more easily and more quickly drilled through with standard rock drilling bits, while at the same time performing all the other functions of the original metal downhole parts or tools. Examples of such tools include mandrels and plugs, while inflatable packer elements may also be included in this grouping.

A wide variety of different materials have been investigated for the purpose of replacing metal parts or tools. Such materials have included a wide variety of plastics as well as a range of phenolic resins, either unreinforced, filled with powers, or filled with short fibers (i.e. 1/4 inch or less) of cotton or glass. While these phenolic resin materials have been satisfactory for fabricating some specific parts which perform certain

functions, many metal replacement opportunities are not open to such materials because the tensile strengths, sheer strengths, stiffness and other important properties are not anywhere near those of the metal materials which are to be replaced. This is particularly true in the well drilling industry, wherein metal replacement parts and tools have been manufactured from phenolic resins reinforced with short fibers of glass. Thus, there remains a distinct need in many industries and product applications for metal replacement parts, components and tools capable of meeting all of the desirable and needed physical properties equivalent to those of the original metal components or tools.

Summary of the Invention

Accordingly, it is one object of the present invention to provide metal replacement components and tools having the same or better physical properties as those of the original metal components and tools which are being replaced.

It is another object of the present invention to provide a composite material capable of being molded to various shapes and forms to provide nonmetallic parts and tools.

It is yet another object of the present invention to provide nonmetallic substitute parts and tools which are expendable and readily abraded.

A further object of the present invention is to provide a composite material molded into a preselected shape to form components and tools for the well drilling industry which are readily drilled through.

To achieve the foregoing and other objects and in accordance with a purpose of the present invention, as embodied and broadly described herein, an expendable, molded device is disclosed. The device is preferably a composite of resin and fiber molded into a preselected shape. The composite includes an effective amount of fiber having an aspect ratio sufficient to produce a device with high compressive and tensile strength but having limited abrasion

resistance. In one particularly preferred embodiment of the invention, the device is in the form of a downhole tool for use in a well bore, wherein the composite fiber aspect ratio provides a sufficiently low abrasion resistance to permit the tool to be destroyed by drilling using a rock drill bit.

Brief Description of the Drawings

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate preferred embodiments of the present invention and together with a description, serve to explain the principles of the invention. In the drawings:

Fig. 1 is a top plan view of a schematic illustrating a sheet of the unmolded compound utilized to form the composite of the invention;

Fig. 2 is a perspective view of a plurality of the sheets as illustrated in Fig. 1;

Fig. 3 is a perspective schematic view of a drill well mandrel formed using the present invention;

Fig. 4 is an enlarged, sectional view of a portion of the threads from a mandrel made with prior art composite material;

Fig. 5 is an enlarged, section view of the threads of a mandrel similar to that of Fig. 4 but formed from the composite of the present invention;

Fig. 6 is a side schematic view of a molding device useful in producing a composite tool of the present invention;

Fig. 7 is an end view of the device illustrated in Fig. 6. with the premolded composite material in position for molding to form a mandrel tool;

Fig. 8 is a top plan view of a fabric reinforcement useful in another embodiment of the present invention;

Fig. 9 is a schematic illustrating a mold portion with a composite precursor for another embodiment of the present invention; and

Fig. 10 illustrates the formation of yet another embodiment of the present invention utilizing the mold arrangement illustrated in Fig. 9.

Detailed Description of the Preferred Embodiments

Referring to Figs. 1-3, sheet 10 is a composite made up of a plurality of fibers 12 embedded in a resin 14. While the fibers 12 may be random in nature, they are preferably oriented in the general direction of the greatest forces to be applied to the finished part, which in the case of a mandrel 16 (Fig. 3) is the longitudinal axis 15 of the sheet 10.

Fig. 2 illustrates the stacking of a plurality of these sheets 10, which stack 11 is then utilized to form the molded structure 16 as illustrated in Fig. 3. In this specifically illustrated embodiment, the molded structural device 16 particularly illustrated is that of a downhole mandrel useful in drilling well bores. It should be noted, however, that the present invention may be used for any type of expendable or destructible structural device that is designed to replace metal components or tools currently in use, and thus have the structural and tensile strength of metal but have low abrasive strength so as to be readily expendable. Specific examples in the drilling industry include mandrels, plugs and packers.

Referring to the preferred, illustrated embodiment, the mandrel 16 is basically a tube formed with external threads 18 on each end thereof, and internal threads, 20 on one end thereof. A mandrel is a tubular device that is placed in bores holes, one atop the other, with an area of the bore hole exposed where there is no mandrel. Thus, an area can be isolated for pumping purposes. However, when it is desired to move operations to another portion of the bore hole, the mandrels must be removed or destroyed in place. Previous hereto, rock drilling bits abraded the metal mandrels very slowly. The alternate maneuver was to insert a metal drilling bit and then change back to a rock drilling bit after the mandrels were destroyed. In either case, a great deal of time was expended.

As I stated earlier, replacement metal devices and components of various sorts have been previously addressed by various industries. Phenolic resins, either

unreinforced, filled with powders or filled with short fibers of cotton or glass, have been utilized. However, parts fabricated from such composites have been unsatisfactory in certain applications because their tensile strengths, sheer strengths, stiffness and other important parameters have not been nearly as great as those of the metal components they were designed to replace. In accordance with the present invention, however, it has been determined that certain combinations of materials and methods allow replacement parts for metal to be designed from resins reinforced by elongated fibrous materials. Preferred resins include, but are not limited to, epoxies, vinyl esters and polyesters, in combination with long (i.e. greater than 1/2 inch) fibers, including but not limited to glass fibers, aramid fibers and carbon fibers. While these long fiber composites typically display greatly improved bulk physical properties as compared to the short fiber phenolic materials previously described, the present invention also provides a distinct advantage in that by controlling the fiber volume, fiber length and fiber orientation, both before and during the molding process, the physical properties in specific areas or portions of the part can be engineered in order to better resist the forces applied to those specific portions of the part when the part is put into use. Thus, composite metal replacement parts having varied properties within itself may be designed utilizing the composite arrangement of the present invention.

As indicated above, the preferred resins include epoxies, vinyl esters and polyesters. The phenolics previously utilized in prior art composites are not useful with the present invention, even in conjunction with long fiber materials. This is because it was found that the materials compounded from phenolic typically displayed physical properties that were at least 20% less than materials combined with the epoxies and vinyl esters of the present invention with equally long fiber reinforcement. Because most, if not all, short fiber phenolic materials have tensile strengths at or below 12,000 psi with other

physical properties also being significantly below those of metals, such as cast iron tensile strength of 30,000-60,000 psi, phenolic replacement parts, even if very thick, will still not meet the requirements of many metal replacement applications.

Utilizing the present invention, replacement composite parts may be designed with physical properties equal to or even exceeding those of the original metal part. With appropriate material choice, proper compounding, proper control of fiber alignment before and during processing, the replacement parts may be designed with tensile strengths having a range of 25,000-100,000 psi or greater. Moreover, an important aspect of the present invention is that a single metal replacement part may be developed with different portions thereof having different physical properties. For example, some portions of a part might be designed to be more flexible, while other portions may be designed to be stiffer, some portions stronger, while some portions being able to resist internal pressure or external crushing.

The mandrel 16 illustrated in Fig. 3 is a cylindrical tube having each end threaded externally 18 and one end internally 20. The mandrel is utilized within a well casing so that it must be capable of withstanding large internal pressures. In order to withstand such pressures, the mandrel must have high tensile and compressive strength, the preferred burst pressure being in the neighborhood of 30-60,000 psi. However, use of the mandrels are such that they remain in the well bore as previously indicated. Therefore, once the mandrels are no longer required, they must be drilled out or abraded away. Previous hereto, the process of drilling out the metal mandrel was a long and tedious one which increased the length of drilling time. This is because the metal mandrel was drilled out by using a rock drilling bit, which took excessive amounts of time to abrade away the mandrel. Alternatively, the drill string was removed from the hole to replace the rock drilling bit with a metal drilling bit to specifically drill through the mandrel, at which time the string was then removed again to

reinstall the rock drilling bit. Either of these traditional techniques increased the drilling time considerably. The composite structure of the present invention, although it has a high compressive and tensile strength, nonetheless has a low abrasion resistance which permits it to be readily drilled through and destroyed by a rock drilling bit. This reduces significantly the amount of time required to drill through the mandrel.

A key feature of the invention which permits the high compressive and tensile strength, but provides a limited or low abrasion resistance, is the high aspect ratio of the fibers in the composite, in addition to the choice of resins and fibers themselves. The aspect ratio is the ratio between the length of the fiber to the diameter of the fiber. In preferred form, the fibers utilized with the present invention are equal to or greater than 1/2 inch and are preferably from 1/2 - 2 inches in length. In some instances, the fibers can be continuous along the length of the sheet 10 and thus along the length of the device 16, to provide extremely high compressive and tensile strength. The high aspect ratio fiber which has a small diameter as opposed to the length of the fiber, substantially increases the amount of surface availability to transfer force from the resin to the fiber. In preferred form, the composite structure of the present invention comprises a resin of bisphenol-a-expoxy or vinyl ester having fiberglass fibers of engineering standard, high strength, or chemically resistant-type. Preferably, the aspect ratio is greater than 1,000. More preferably, the aspect ratio is in the neighborhood of 2,500-90,000 or more, in the case of continuous fibers, and most preferably in the neighborhood of 2,500-5,000.

Another advantage to the present invention is in the threading and thread connection of any metal replacement devices, and in particular of the illustrated mandrel in Fig. 3. Referring to Figs. 4 and 5, Fig. 4 represents a prior art arrangement utilizing phenolic resins and short fibers. As is illustrated, the teeth 22 of the thread portions 18' are for the most part void of any short fibers

24 and are generally made up of resin 26 and filler 28. Thus, the teeth 22 of the threads 18' are resin rich, which tended to cause stripping of the threads 18' under high pressure since there are relatively few adhesive fibers within the teeth 22. Referring to Fig. 5, the threads 18 of the present invention include teeth 22 which have a substantial number of the long fibers 30 therein. In fact, the teeth 22 are fiber rich as opposed to resin rich as in the prior art 18'. The fiber rich teeth 22 are due to the fact that the fibers 30 are relatively long in length and are thus pressed into the teeth 22 and, in fact, thread themselves through several teeth 22, thereby increasing their strength to act together. The results are that the thread portions of the mandrel 16, or any other device having threads 18, are very strong and do not tend to sheer under high pressure.

Such expendable, molded composite devices, as replacement parts for metal components, have a wider range of application because of a number of unique features. First, the tensile properties of such composite components equal or exceed those of the original metal part, which will allow this type of replacement part to be fabricated within the same design envelope as a metal part or even less. Second, the sheer strength of such a composite replacement material is possibly less than the original metal material sheer strength. However, by virtue of the long fiber reinforcement being molded actually down into the threads 22 on the ends of the mandrel 16 as described above, with these fibers being long enough to pass both into and out of multiple threads, and by virtue of these long fibers being able to share the load that would be required over a relatively large area, the threads on a metal replacement composite part designed from this composite material are placed in tension as well as sheer. This results in threads that perform better than any short fiber reinforced resin, and also better than is apparent from the bulk sheer strength of the replacement material. Actual testing of mandrels formed from the present invention correlate with this.

Referring to Figs. 1-3, 6 and 7, the mandrel 16, as well as any other desired composite device, may be molded into metal replacement components using compression and/or transfer molding techniques. To form the mandrel 16, a mold 32 having a bottom mold portion 34 and a top mold portion 36 is provided. A rod 38 is also provided to form the center cavity of the mandrel 16. In the preferred form, the bottom mold 34 is a female mold and is operated by placing a plurality of the composite sheets 10 down within the female cavity 40. The center rod 38 is then placed within the female cavity 40 on top of the layered sheets 10. A plurality of sheets 10 are then placed over the rod 38. The upper mold 36, having a male cavity 42, is then pressed downwardly into the bottom mold 34 so as to compress the overlaid sheets and underlaid sheets 10 around the rod 38 within the male and female cavities 42, 40. The male upper mold 36 is guided into position by guideposts 44 and sockets 46. The female cavity 40 has threaded grooves 48 at either end thereof, while the male cavity 42 likewise has threaded grooves 50 at either end thereof to form the external threads 18 on the mandrel 16. In similar fashion, a forward portion 54 on the rod 38 also has threaded grooves to form the internal threads 20 of the mandrel 16.

In preferred form, the rod 38 and the layers of uncompressed composite 10 are positioned as illustrated, the molds 34, 36 being brought together and heated under pressure. Preferably, the composite material 10 is pressurized 2,500-4,000 psi for a sufficient time and temperature such that maximum density of the composite material and sufficient flow so that all interstices and junctures between the sheets 10 are completely filled.

As indicated previously, one of the principal advantages of the present invention is that it may function as a substitute for metal devices or components in a wide variety of different applications from automobiles to drilling well bores. Regardless of this application, the composite materials should be utilized in an environment which will not tend to degrade the composite material and thus reduce the strength of the composite device. Table III

below indicates a summary of the chemical resistance of composite materials constructed in accordance with the present invention as compared to the prior art phenolic composite. As can be seen from Table I, the composite device of the present invention has much better chemical resistance to a wider variety of chemical materials found in the environment than the prior art phenolic composite.

Table I

Chemical Resistance of Composite
Materials Compared to Phenolic

CHEMICAL ENVIRONMENT	MATERIAL DESCRIPTION III	I & II	Phenolic
Aliphatic Hydrocarbons	Good	Ex	Ex
Aromatic Hydrocarbons	Good	Good/Ex	Ex
Oils, Fats, Waxes	Ex	Ex	Ex
Fully Halogenated Hydrocarbons	Ex	Ex	Ex
Partly Halogenated Hydrocarbons	Good	Good	Ex
Alcohols Monohydric	Ex	Ex	Good
Alcohols Polyhydric	Ex	Ex	Ex
Phenols	Fair	Fair	Ex
Ketones	Fair	Fair	Good
Esters	Fair	Good	Good
Ethers	Fair	Fair	Ex
Conc. Inorganic Acids	Good	Fair	Fair/Poor
Dilute Inorganic Acids	Ex	Ex	Fair/Good
Conc. Bases	Fair	Ex	Poor
Dilute Bases	Good	Ex	Poor
Salts - Acid	Ex	Ex	Ex
Salts - Neutral	Ex	Ex	Ex
Salts - Basic	Good	Ex	Fair
Conc. Organic Acids	Good	Fair	Good
Dilute Organic Acids	Good	Good	Fair
Conc. Oxidizing Acids	Poor	Poor	Poor
Dilute Oxidizing Acids	Fair	Fair	Poor
Sunlight and Weathering	Good	Good	Good

All of the composite materials I-III included either a vinyl ester resin (III) or a bisphenol-a-expoxy resin (I & II) having 60-70 weight percent of glass fiber. Composite I had the glass fiber laid in a directional manner substantially parallel with the longitudinal axis of the sheet 10. Composites II and III were made with the glass fibers placed within the resin in a more random fashion. The phenolic material was a glass fiber reinforced phenol having short fiber lengths as described above.

The composite components of the present invention also have an excellent temperature resistance in terms of maintaining their tensile and flex strength at elevated temperatures such as found in certain engine compartments or such as found in bore holes at depth. This is true also in corrosive environments at temperatures approaching 300°F. Thus, composite devices constructed in accordance with the present invention will not tend to fail when utilized in higher temperature environments, and therefore function quite well as metal replacement components.

Downhole mandrel 16, as illustrated in Fig. 3, may be manufactured using the method and mold described in Figs. 6-7. Depending on the diameter of the rod 38, a thin wall mandrel yielding a larger inner diameter device, or a thick wall mandrel producing a thinner diameter device, may be manufactured. However, the burst strength of such mandrels will be different. For example, a mandrel 16, manufactured in accordance with the method and mold described above, may be made having an outer diameter of 2.375 inches and an inner diameter of 1.333 inches with a wall thickness of 0.521 inches. Material strength for this, as well as the subsequent mandrel example, is 50,000 psi, and the burst strength results in about 39,085 psi. A second mandrel 16 is manufactured having the same outer diameter of 2.375 inches. However, a wider rod 38 is utilized so as to form an inner diameter of 1.754 inches, resulting in a wall thickness of 0.311 inches. The material strength is the same 50,000 psi, and the resultant burst strength, however, is reduced to 17,702 psi.

In either of these instances, however, the burst strength is significantly greater than equivalent type of mandrel made from the phenolic material described above. Utilizing the same measurements as given above, phenolic material at 12,000 psi material strength will result in a burst strength of 9,380 psi for the thick wall mandrel and only 4,249 psi burst strength for the thin wall mandrel. Therefore, it can be readily seen that a mandrel, or any other tool or component, constructed in accordance with the present invention has a significantly greater burst strength

than mandrels made from composite materials known previously hereto. These burst strengths are sufficiently adequate to allow the mandrels manufactured in accordance with the present invention to readily replace metal mandrels, and thereby have the inherent advantages of the composite as far as being expendable as described above.

An alternate embodiment and manufacture of mandrel 16 utilizing the mold substantially as illustrated in Figs. 6 and 7, is illustrated in Figs. 8-10. Fig. 8 illustrates a woven fabric 60, which is produced from long fibers, in fact continuous in length, woven together and impregnate with the resin as described above. This particular woven fabric 60 may be utilized to produce reinforced threads on a mandrel 16. This is performed by utilizing the same mold 32 as illustrated in Fig. 7. However, an alternate form of rod 38' having threads 62, are provided. This is illustrated in Fig. 9.

As illustrated in Fig. 10, the woven fabric 60 is wrapped around the rod 38' and then the sheets 10 of uncompressed composite material are wrapped around the non-threaded portion of the rod 38' over the fabric layer 60. Compression molding in the matched die molds 34, 36 form the outside of the part or mandrel and force the fabric layer 60 into the thread 62 of the rod 38', forming female threads on the internal diameter of the molded mandrel 64. In addition, if the molded mandrel 64 or other molded device are required to be extremely strong in tension or extremely stiff in bending along its major longitudinal axis, then the continuous fiber reinforcement applied along the longitudinal axis of the part from the woven fabric 60 will enhance these properties. All of these possibilities are realized using compression molding techniques with the composite of the present invention and are not available to a compression or injection molded part made from just short fiber reinforced phenolics as in the prior art. In addition, layers of the fabric 60 would also serve to increase burst strength as well as to serve to improve crush resistance of a mandrel 64.

As a final example, continuous fibers, spiral continuous fibers or braid continuous fibers can be filament wound in any combination with fabric layers 60 and random mat layers over rods 38 that are of appropriate shape. Such rods or other mold portions could be made of low melt temperature metal such as bismuth alloy, or of wax. Such techniques in combinations allow incredibly greater latitude in the design of high strength, engineered, metal replacement parts, including but not limited to easily drillable downhole products for the drilling industry, as well as any other type of expendable metal replacement part.

As can be seen from the above, the present invention provides for expendable, molded structural products and devices which are useful in a wide variety of industries. These are particularly useful as drillable downhole products for the drilling industry. The products are of sufficient structural and compressive strength to be able to function as metal replacement parts in a wide variety of applications. However, because of the unique nature of the present invention, the products have a very low abrasion resistance and thus are readily expendable or, in the case of the drilling industry, readily drillable and destructible so as to remove them from the well by simply utilizing a rock drilling bit, without an extensive increase in the amount of drilling time necessary. Devices produced with the present invention provide some unique alternatives in a wide variety of applications to replace metal products or metal components which either need to be destroyed in situ or wherein weight is of a major concern.

The foregoing description and the illustrative embodiments of the present invention have been shown in the drawings and described in detail in varying modifications and alternate embodiments. It should be understood, however, that the foregoing description of the invention is exemplary only, and that the scope of the invention is to be limited only to the claims as interpreted in view of the prior art. Moreover, the invention illustratively disclosed herein suitably may be practiced in the absence of any element which is not specifically disclosed herein.

The embodiments for which an exclusive property or privilege is claimed are defined as follows:

1. An expendable, molded device comprising a composite of resin and fiber molded into a pre-selected shape, said composite including an effective amount of fiber having an aspect ratio sufficient to produce a device with high compressive and tensile strength but having limited abrasion resistance.

2. The device as claimed in Claim 1, wherein said fiber aspect ratio is greater than about 1,000.

3. The device as claimed in Claim 2, wherein said fiber aspect ratio comprises 2,000-90,000.

4. The device as claimed in Claim 3, wherein said fiber aspect ratio comprises 2,500-5,000.

5. The device as claimed in Claim 1, wherein said fiber is substantially continuous and aligned in the direction of the major forces to be applied to said device.

6. The device as claimed in Claim 1, wherein said effective amount of fiber comprises approximately 60-70% by weight of said composite.

7. The device as claimed in Claim 1, where said composite is molded at approximately 2,000-4,000 psi.

8. The device as claimed in Claim 1, wherein the abrasion resistance of said composite is sufficiently low to permit rapid abrasion by metal.

9. The device as claimed in Claim 8, wherein the abrasion resistance of said composite is sufficiently low to permit said composite to be easily drilled through and abraded away by a rock drill bit.

10. The device as claimed in Claim 1, wherein said resin is selected from the group consisting of epoxies, vinyl esters and polyesters, and wherein said fibers are selected from the group consisting of fiberglass, aramids and carbon fibers.

11. The device as claimed in Claim 1, wherein said fibers are equal to or greater than 1/2 inch in length.

12. The device as claimed in Claim 11, wherein said fibers are elongated and are from 1/2 - 2 inches in length.

13. A drillable, downhole tool for use in a well bore comprising a composite body of resin and fiber molded into a predetermined shape, said composite including an effective amount of fiber having an aspect ratio sufficiently high to provide said body with high compressive and tensile strength and low abrasion resistance to permit said tool to be drillable.

14. The tool as claimed in Claim 13, wherein said effective amount of fiber comprises approximately 60-70 weight per cent of said composite body.

15. The tool as claimed in Claim 13, wherein said fiber is sufficiently elongated relative to its diameter to provide said high aspect ratio.

16. The tool as claimed in Claim 15 wherein said fiber aspect ratio is greater than about 1,000.

17. The tool as claimed in Claim 16, wherein said fiber aspect ratio comprises 2,500-5,000.

18. The tool as claimed in Claim 13, wherein said fiber is substantially continuous and aligned in the direction of the major force to be applied to said tool.

19. The tool as claimed in Claim 13, wherein said abrasion resistance is sufficiently low such that said tool is destructible in situ within said well bore by a rock drill bit.

20. The tool as claimed in Claim 13, wherein said tool comprises a downhole mandrel having a burst strength of approximately 30,000-60,000 psi.

21. The tool as claimed in Claim 20, wherein said fiber is sufficiently elongated to provide said high aspect ratio and is substantially aligned with the longitudinal axis of said mandrel.

22. A drillable downhole mandrel for use in a well bore comprising a composite body of resin and fiber molded into a mandrel, said said composite comprising an effective amount of long fiber having a high aspect ratio sufficient to provide said body with high compressive and tensile strength and sufficiently low abrasion resistance to permit said mandrel to be readily destroyed in situ by being drilled through.

23. The mandrel as claimed in Claim 22, wherein said resin is selected from the group consisting of epoxys, vinyl esters and polyesters, and wherein said long fibers are selected from the group consisting of fiberglass, aramids and carbon fibers.

24. The mandrel as claimed in Claim 22, wherein said composite comprises vinyl ester having 60-70 weight percent fiberglass fibers.

25. The mandrel as claimed in Claim 22, wherein said fiber aspect ratio is greater than about 1,000.

26. The mandrel as claimed in Claim 25, wherein said fiber aspect ratio is 2,500-5,000.

27. The mandrel as claimed in Claim 22, wherein said long fibers are elongated and aligned substantially with the longitudinal axis of said mandrel.

28. The mandrel as claimed in Claim 27, wherein said fibers are substantially continuous along the length of said mandrel.

29. The mandrel as claimed in Claim 22, wherein said mandrel has a burst strength of approximately 30,000-60,000 psi.

30. A drillable downhole tool for use in a well bore comprising a non-metallic tool body having high compressive and tensile strength yet effectively low abrasion resistance to permit said tool to be destructible in situ within said well bore by a rock drill bit.

31. The tool as claimed in Claim 30, wherein said compressive and tensile strength are sufficiently great to provide a burst strength of about 30,000-60,000 psi.

32. The tool as claimed in Claim 30, wherein said body comprises a long fiber composite having resin and fiber combined to provide a high fiber aspect ratio.

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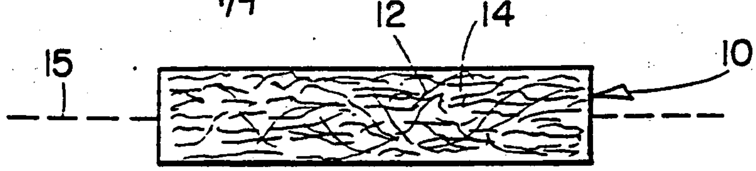


FIG. 1

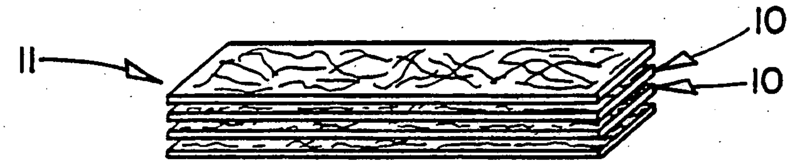
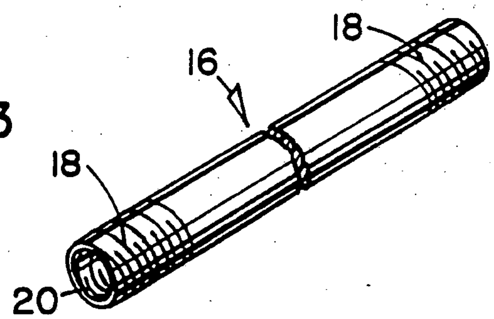
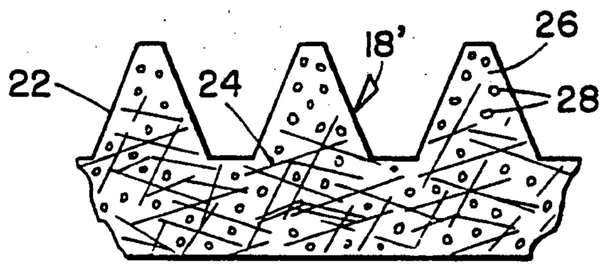


FIG. 2

FIG. 3





Prior Art

FIG. 4

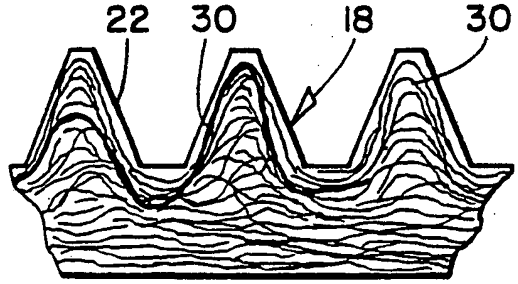


FIG. 5

FIG. 6

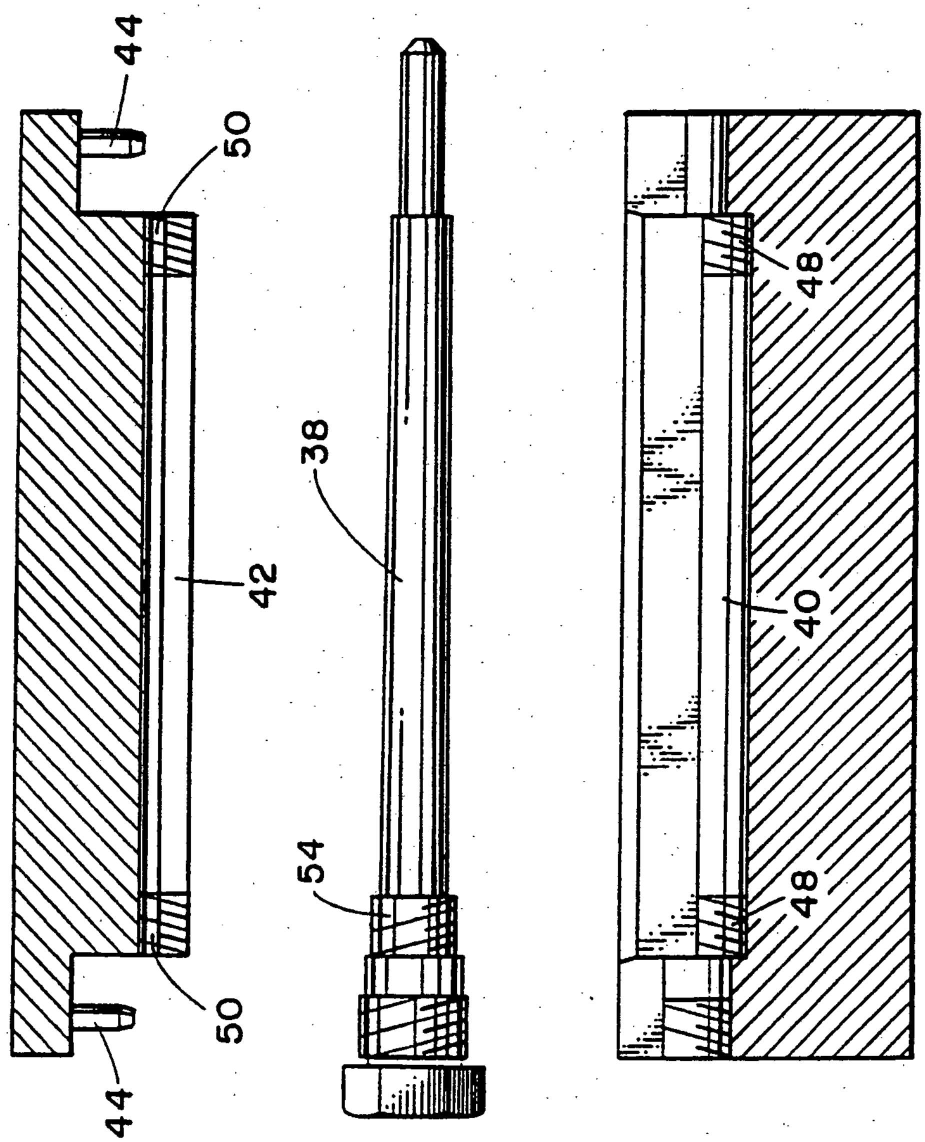
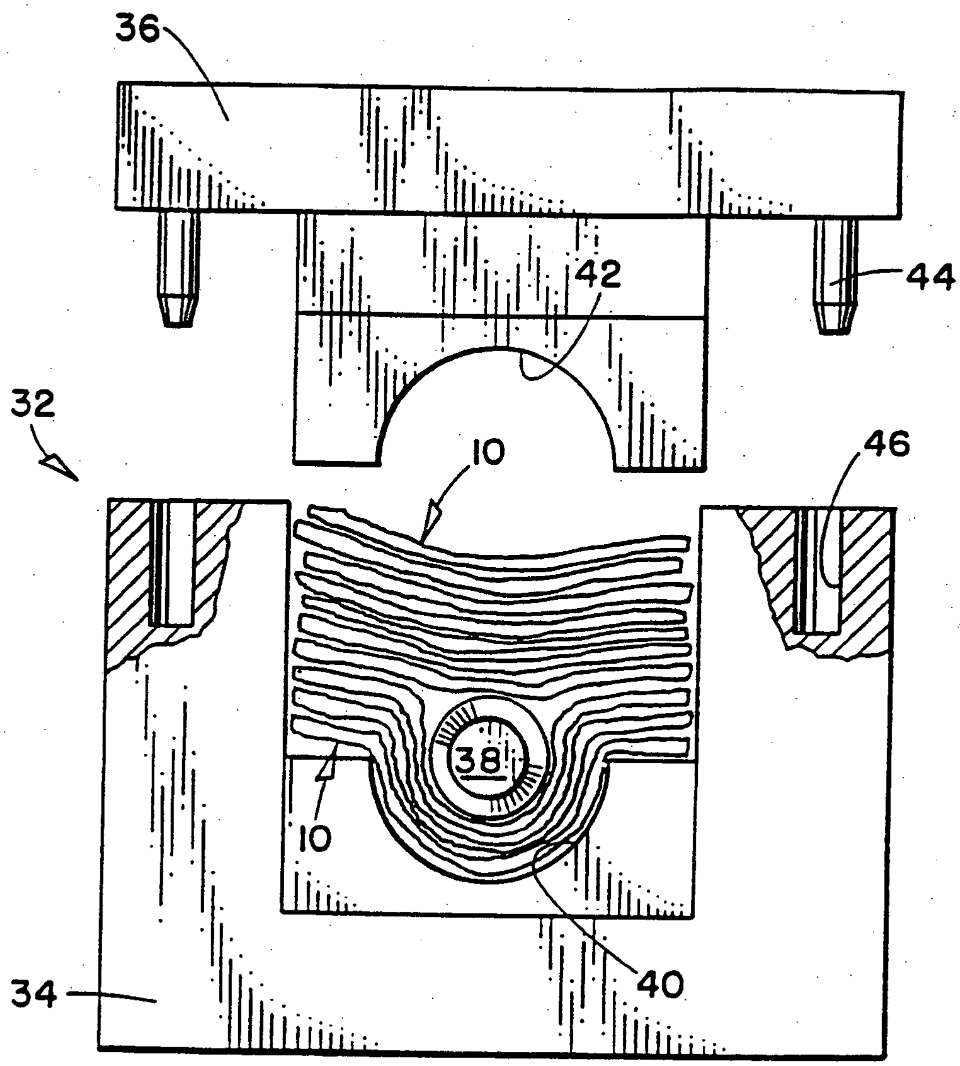


FIG. 7



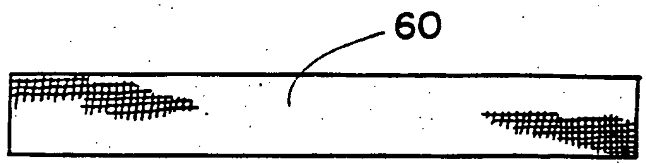


FIG. 8

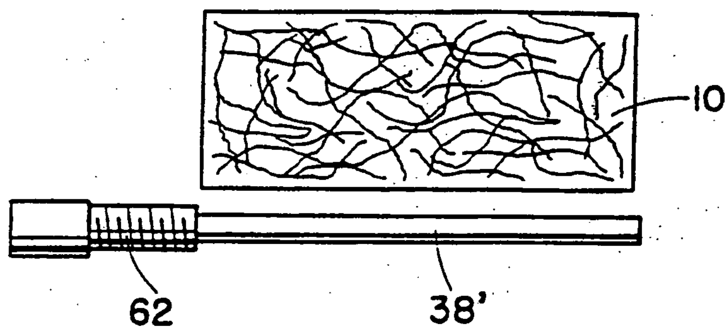


FIG. 9

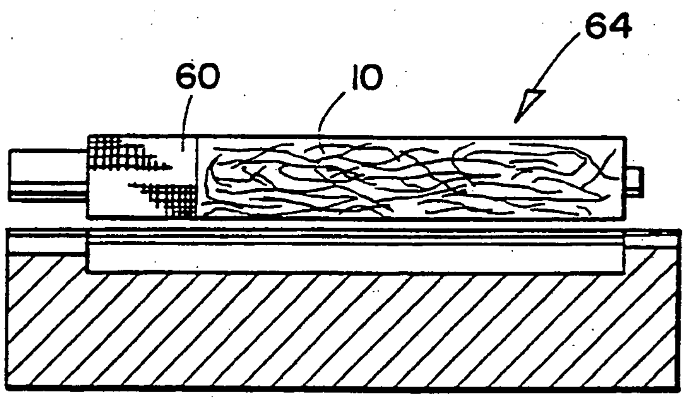


FIG. 10

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 92/04365

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl.5 E 21 B 33/12 B 29 C 67/14

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl.5	E 21 B B 29 C

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
X	US,A,4708202 (SUKUP) 24 November 1987 see the whole document ---	1,5,8,9,10,13,15,18,19,20,21,30-32
P,X	EP,A,0454466 (HALLIBURTON) 30 October 1991 see column 3, line 40 - column 4, line 31; claims 1-5; figures 1,2 ---	1,8,9,13,15,19,22,23,27,28,30,32
A	FR,A,2567807 (BRONZAVIA) 24 January 1986 see page 1, lines 12-26; claims 1,3,4,6,7,8; figures 1-6 --- -/-	1,10,15,21,23,27,32

° Special categories of cited documents : [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
20-08-1992	11. 09. 92
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	FONSECA Y FERNANDEZ

International Application No PCT/US 92/04365

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	WO,A,8809263 (TEXTILVER) 1 December 1988 see page 1, lines 1-11; page 5, lines 1-11 ---	5,18,28,32
A	EP,A,0324630 (RAYCHEM LTD) 19 July 1989 see claims 1,6,20 ---	1,10,23
A	EP,A,0104958 (ALBANY INT.) 4 April 1984 see abstract; figures 1-4 ---	5,8,27,28
A	EP,A,0191337 (HAREN) 20 August 1986 see abstract; figure 1 -----	1

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. US 9204365
SA 61092

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 08/09/92
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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A- 4708202	24-11-87	None		
EP-A- 0454466	30-10-91	AU-A-	7594991	07-11-91
FR-A- 2567807	24-01-86	None		
WO-A- 8809263	01-12-88	GB-A-	2204888	23-11-88
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EP-A- 0104958	04-04-84	None		
EP-A- 0191337	20-08-86	DE-A-	3504829	14-08-86

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82